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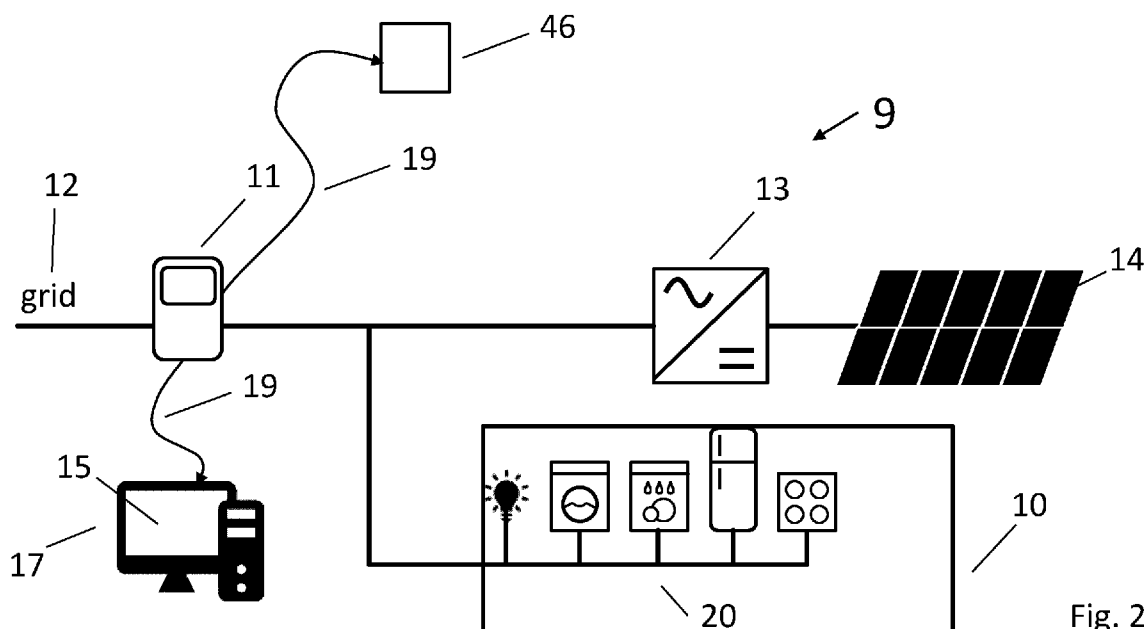


Fig. 2

(57) Abstract: Methods, devices and systems for generating electrical energy certificates, herein called Real-Time Guarantees of Origin, RTGOs. Methods, devices and systems for determining an operative state of an electricity supply or distribution network on the basis of the RTGOs, as well as computer programs for carrying out the methods. Methods, devices and systems for using an operative state of an electricity supply or distribution network in control of that network, e.g. in a remedial action as well as computer programs for carrying out the methods. Methods, devices and systems for identifying origin of stored products created by use of electrical energy.

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Methods and Systems for Generating Real time Guarantees of Origin and Determining the Operative State of an Electricity Network

The present invention relates to methods, devices and systems for generating electrical energy certificates, herein called Real-Time Guarantees of Origin, RTGOs. The present invention relates to methods, devices and systems for determining an operative state of an electricity supply or distribution network on the basis of the RTGOs, as well as computer programs for carrying out the methods. The present invention can relate to methods, devices and systems for using an operative state of an electricity supply or distribution network in control of that network, e.g. in a remedial action as well as computer programs for carrying out the methods. The present invention can relate to methods, devices and systems for identifying origin of stored products created by use of electrical energy.

Background

In a liberalized electricity market, customers have the choice to buy electricity from many different suppliers. This has led to a very competitive market where energy supply companies try to attract customers not only with low prices but also by creating distinct contracts/products with a specific energy mix. In particular, electricity produced by means of renewable energy sources has gained popularity in the last decade due to, for example, subsidy programs, decreasing prices, and strong general environmental awareness. Offering some minimum guaranteed fraction of renewables within their energy mix, suppliers can thus distinguish themselves among their competitors.

However, tracing the use of electricity from renewable sources in a large electric grid which can be transnational in size is not trivial. The same properties of the electricity transportation and distribution infrastructure (the electricity grid) that enable the virtualization and thus the liberalization of the market make it more difficult to know the true state of the system. Once inside the grid, electricity produced from renewable sources becomes indistinguishable from electricity produced from other sources. This is likewise the case for any attribute of electricity production that might conceivably contribute to provider or user appreciated goals. For that reason, there is a need for an electricity tracking system which allows determination of the operative state of the electricity supply or

distribution network and to track specific electricity attributes from the production to consumption regardless of the physical electricity flows.

5 The establishment of a tracking system for attributes of electricity generation from the supplier to the consumer so far has been driven by environmental concerns. The United Nations Framework Convention on Climate Change (UNFCCC) (1992) recognized the necessity to limit and reduce carbon dioxide emissions. It was extended first by the Kyoto Protocol (1997) which implements the goal of the UNFCCC to reduce greenhouse gas concentrations in the atmosphere and lists “Research on, and promotion, development and
10 increased use of, new and renewable forms of energy [...]” as an objective, and later by the Paris Agreement (2015).

In this context, various economy-based certification schemes have been created and are currently used that treat environmental impact as tradable commodity or at least attach
15 monetary ramifications on ecologic effects. Examples include:

- Assigned amount units (AAU) represent the national allowance of equivalents of one metric ton of carbon dioxide in terms of greenhouse potential (“Kyoto Unit”). These allowances can be traded between countries that have spare allowance and countries that exceed their emission targets. The largest trading schema is the European Union Emission
20 Trading Scheme (EU ETS). This system manifests the idea of cap and trade pollution markets that trade pollution/emission licenses.
- Certified emission reductions (CER) are the control mechanism within the Kyoto protocol for countries about keeping their AAU targets.
- Eco tariffs are devised to subsidise environmentally preferable products (EPP) and
25 penalize cheaper competition based on environmentally harmful methods (“eco-dumping”) through customs and taxation.

Particularly the following are tailored to the processes of feeding energy into or obtaining energy from the electricity grid:

- 30
- Green certificates are a way of certifying that a specific amount of electricity fed into the grid was generated from renewable (“green”) sources. A consumer can buy these certificates in order to establish that certain amounts of renewable energy was fed into the

grid on his behalf. An example of green certificates is the Renewable Energy Certificate System (RECS), a voluntary system created by RECS International (founded in 2002).

- Guarantees of origin (GO) are a European extension to Renewable Energy Certificates (REC) in terms of scope and legal aspects.

5

Renewable Energy Certificates (REC) represent a voluntary mechanism for trading green aspects of electricity transported through the grid. With the Directive 2001/77/EC and later amended in article 15 of the European Renewable Energy Sources Directive (2009/28/EC) the European Parliament and Council introduced Guarantees of Origin (GO) as being the mechanism for, “proving to final customers the share or quantity of energy from renewable sources in an energy suppliers energy mix”. These GO enhance and replace the various national green certificates including the transnational REC. They implement a system to deliver electricity attributes to the consumer in parallel to the physical delivery of the electricity.

15

Conceptually, the directive defines the following properties for a GO (as relevant to the present invention):

- A guarantee of origin shall be of the standard size of 1 MWh. No more than one guarantee of origin shall be issued in respect of each unit of energy produced.
- 20 • Any use of a guarantee of origin shall take place within 12 months of production of the corresponding energy unit.
- A guarantee of origin shall be cancelled once it has been used.
- A guarantee of origin shall specify at least:
 - 25 ○ the energy source from which the energy was produced and the start and end dates of production;
 - the identity, location, type and capacity of the installation where the energy was produced;
 - whether and to what extent the installation has benefited from investment support, whether and to what extent the unit of energy has benefited in any other way from a national support scheme, and the type of support scheme;
 - 30 ○ the date on which the installation became operational;
 - the date and country of issue and a unique identification number.

- Electricity suppliers are required to prove the share or quantity of energy from renewable sources in its energy mix, they may do so by using its guarantees of origin.
- A guarantee of origin can be transferred, independently of the energy to which it relates, from one holder to another.

5

In practice, the demand for GOs has been higher than the amount of GOs which are produced by renewable energy sources and hence a market was created to trade GOs. This market uses the principles of supply-and-demand to provide the GO certificate, the carrier of European electricity attributes, with a price. This supply-and-demand market for GOs is known as the voluntary renewable energy market.

10

Further, the European legislation requires that member states put appropriate mechanisms in place to ensure that guarantees of origin shall be issued, transferred and cancelled electronically and are accurate, reliable and fraud-resistant.

15

Already before the EC legal framework was in place, a number of member states started working together since 2002 on a voluntary basis to define a format to standardize and exchange GOs in cooperation with the Association of Issuing Bodies (AIB). AIB is a non-profit association with members from EU and EEA states, which developed a digital format for GOs and operates a joint IT-HUB to facilitate the transfer of GOs between several national GO registries. The developed format is called EECS (European Energy Certificate System) and is considered the de facto standard on GOs. The EECS format is the foundation for CEN standard EN 16325 “Guarantees of Origin related to energy – Guarantees of Origin for Electricity” which also covers the certification.

20

25

Each EECS certificate is uniquely identifiable, transferable and therefore tradable, and contains standard information on the source of the energy, and its method of production. The Principles and Rules of Operation of the European Energy Certificate System (the EECS Rules) defines a certificate as an electronic document which identifies the source and method of production of a unit of energy and relates to a specific purpose – such as energy source disclosure or compliance with an obligation. It also prohibits certificate holders from separately claiming or conferring rights or title to any element of this benefit, and for this purpose.

30

Certificates are created, change owners and are eventually made non-transferable under a carefully developed and managed control infrastructure, the EECS Rules, as interpreted by each country or region according to its "Domain Protocol". The adequacy of this interpretation is assured by the other AIB members as a condition of membership.

5

The trading of the EECS and prices are exchanged between market participants and can happen over the counter or via exchanges. The AIB website gives a list of known EECS brokers on their website but clearly indicates that the list does not represent the entire market.

10

Various schemes exist that aim to enhance the RECS and the current GO system. Two main aspects can be distinguished:

1. Introducing more transparency through credible standards by trusted organizations and accreditation schemata that aim to guarantee that electricity is produced from genuinely sustainable sources and/or that the environmentally positive aspects of electricity generation exceed legal requirements.
2. Developing alternative certification schemata that simplify trading, inhibit fraud, and/or eliminate the necessity for middle-man and/or central supervision.

Examples for stricter and more credible standards include the EUGENE standard developed under the lead of the World Wildlife Fund (WWF) that accredited national energy labels in Germany and Switzerland and was in the process of accrediting national energy labels in Finland, Netherlands and Sweden. The EUGENE General Assembly and association dismantled in 2009, but the standard and national labels still exist.

Alternative certification and/or trading schemata generally emphasize the use of cryptographic distributed ledgers (blockchain technology). Peer to peer trading of energy using blockchain technology for example is offered by Power Ledger in Australia, which aims to circumvent utility companies. In a similar way, We Power uses blockchain transactions to enable direct trade between producers and consumers. Likewise, the UK based company Electron focusses on blockchain for metering and trading energy production and consumption. Energy Web Foundation aims to find general uses of blockchain technology in energy trade to reduce transaction costs. Grid+ aims to use energy trade as a vehicle to move towards a general acceptance of crypto currencies. The Brooklyn, NY, USA based company LO3Energy uses blockchain technology to trade excess energy

inside microgrids between buildings. Their platform called Exergy offers mobile apps, special metering devices, and a platform to build virtual microgrids. Finally, PwC published a study which was conducted on behalf of Verbraucherzentrale NRW, Dusseldorf where the potential use of block chain technology for Guarantees of Origin is mentioned (pg. 33):

5 “Thanks to its synchronicity (generation and consumption) and capability to provide clear and verifiable records, block chain would be the first technology to make it possible for the source of electricity to be determined. Guarantees of origin could be issued with greater certainty. This would also make it easier to issue certificates for emission allowances and energy efficiency improvements, which would in turn simplify the complex systems
10 currently used.”

Further uses of blockchain in energy include the Dutch TSO TenneT, which uses blockchain technology in a pilot project to connect privately owned household batteries into a swarm, or the RWE spin off Innogy which connects drivers of electric vehicles with
15 providers of charging stations using blockchain without the need of an intermediate authority.

The systems have in common that they emphasize the use of blockchain and try to eliminate central authorities or natural monopolies. Their business models are based on the use of a
20 distributed ledger.

There is broad criticism against the current REC/GO system. Some of the identified shortcomings include:

- Energy providers can buy certificates from renewable energy plants that have
25 existed for years, effectively stifling the need to make investments of their own into renewable sources. Thus, some consider the actual positive ecological impact of REC as rather low. Instead of increasing the fraction of renewable energy in the overall mix, REC/GO can be used to reassign green energy to ecologically aware consumers on the expense of the fraction of green energy sold to non-ecologically aware users.
- An REC/GO is effectively an exchange of attributes between different forms of
30 electricity generation: A plant using renewable sources that sells REC/GO to a consumer inherits the attributes of the electricity that the buyer of the REC/GO actually consumes from the grid. As this exchange is not necessarily transparent, this can lead to a situation in which a supplier known for the eco-friendliness of its generation plants can legally sell grey

energy to their customers and market the eco-friendliness of their electricity separately. In other words, the uniqueness of the certificate in itself does not guarantee the uniqueness of the allocation of the energy package. It frequently happens that the environment-friendly energy referred to in a GO certificate has already been consumed and paid for by local customers who are confident of its CO₂-clean origin (e.g., they are connected to a local grid in Norway that only carries CO₂-clean energy) and had no (other) reason to buy energy certificates for their own consumption. Currently the EECS indiscriminately provides for the certification of these energy packages and brings these certificates to the market to sell them to other consumers.

The net effect is that, even if good money was paid willingly for the certificate by trustful and environmentally conscious consumers, *no contribution* was made whatsoever to the shift towards clean energy production, as the consumer paying for the certificates may very well have consumed only “grey” or “dirty” energy. Hence the energy producer is not incentivised to invest in cleaner energy generation.

RECs can be used to mask the actual source of energy sold within the European market. For example, 100% nuclear energy electricity can be sold as green energy if REC/GO for the same amount of energy were purchased. The producer of the green electricity may now receive the label for “grey” electricity from the certificate trader, reflecting the general mix of energy in the European UCTE network for energy of unknown provenance. The actual source of the electricity from nuclear production is then hidden.

The roots of the current system of GOs go back to 2001 at a moment in time when renewable energy production in most EU countries was limited, except for countries where the topographic and geological conditions are suited for hydro power. A system was put in place which guarantees that the energy consumed by customers with a renewable energy contract on a yearly basis is produced by renewable energy sources. Part of the intent was to decouple the provision of renewable energy into the grid in terms of time and location from the appreciation and monetarization of the environmentally desirable effects (possibly at a different time and location) in order to direct investment into those areas where the greatest effects could be accomplished with the least amount of resources and to allow consumers to opt for renewable energies even if the local circumstances inhibit sufficient harvesting of renewable energies within their vicinity. The existing system has perfectly

served the goal to double the share of renewable electricity production in the last decade (from 14.8% in 2005 to 28.8% in 2015 in Europe).

5 The current system however does not ensure that the consumer actually receives electricity from renewable energy sources in real time. At moments when there is not a sufficient amount of renewable electricity available (e.g. during the night, no sun, no wind) or at places, where conventional sources are simply closer and more economic, consumers with a renewable electricity contract will receive electricity from conventional (e.g., fossil fuel powered or nuclear) power stations. At times and places when where there is a large amount
10 of renewable electricity available, extra GOs are generated to cover for the moments no renewable electricity was available.

The system of trading GOs in their current form definitely has advantages for the customer: It ensures that growing interest of customers in renewable energy is covered by the
15 production of electricity from renewable energy sources with a guaranteed supply of electricity even at moments when intermittent renewable energy sources are not available. However – and this comes in addition to the shortcomings that were mentioned already in the previous section about prior art – the real time availability and intermittent character of the renewable energy source is completely hidden for the customer.

20

It is important to mention that customers are often not aware of the rules for renewable electricity contracts and GOs. While customers with a 100% renewable electricity contract assume they receive electricity from renewable sources:

- This is not the case in real time.
- 25 • It is perfectly possible that their supplier produces electricity with non-renewable sources and buys GOs on the market to create 100% renewable energy contracts.

In essence, the main technical difference between conventional and renewable energy sources is that the former generally come from a finite and depletable (i.e., non-renewable)
30 but controllable *stock* of energy (fossil or nuclear fuels), while the latter come from a virtually infinite and non-depletable but volatile and uncontrollable *source* (solar radiation, wind). Conventional energies can be used at will until depleted while renewable energies, although never depleted, have to be harvested whenever available. With the fraction of renewables increasing in the energy mix, the effects of this difference become more and

more pronounced. Rather than how much energy is consumed (due to finiteness) it becomes more important at what time energy is consumed (due to volatility).

5 However, as the current system – which is meant to support the growth of the fraction of renewables in the energy mix and has done so in the past – hides their intermittent character, it practically inhibits further growth, as it delays the necessary paradigm shift from *how much* to *when* energy is consumed. Under the assumption that customer electricity consumption patterns remain the same and even under the assumption that only investments in renewable energy sources will be done, it will not have a large effect on the further
10 reduction of conventional, environmentally harmful, energy sources. Conventional energy sources will still be needed to cover moments in time when there is not a lot of wind and/or sun, while renewable energy sources will be curtailed at other moments in time when too much renewable energy is available.

15 Plenty of technical solutions are available to help coping with the above issue:

- creating balanced portfolios of complementary renewable energy sources with wind, sun, hydro power, biofuels, etc.
- small and large-scale storage technologies as pumped hydro, batteries, compressed air, power-to-gas, ...
- 20 • grid reinforcements which couple different geographical areas with complementary meteorological and geological properties, ...
- active increase of electricity consumption at times when a large amount of renewable electricity is available or active decrease of electricity consumption when renewable electricity production is limited (demand response, demand side management).

25

But, as in today's 100% renewable electricity contracts, it is (nearly) impossible to see the difference between:

- an electricity supplier who only buys GOs on the market,
- an electricity supplier who does a genuine effort to invest in renewable energy
30 sources,
- an electricity supplier who wants to invest in renewable energy sources and infrastructure to cope with the intermittent character of renewable energy,

- investments into these technical solutions does not lead to an economical advantage in terms of a distinction of the supplier visible/transparent to the customer.

US 2013/007458 A1 describes a system where energy is exchanged between electrical storage devices that are each connected to a green electricity generator. The exchange of energy is triggered by manual interaction. Digital signatures that can be verified by a certificate authority are used to identify the participants in this exchange in the same way digital signatures commonly work in consumer cryptography, for example in PGP e-mail communication.

US 2015/134440 A1 relates to a system to manage the consumption of 'green' energy introduced into a power distribution network together with the energy obtained from other sources, distributed to predetermined delivery points. The green energy is associated to RECS certificates of origin, whose economic value is proportioned to the energy production. The power distribution network includes a consumption counter for computing the total energy consumption in a plant. A server is associated with the power distribution network for managing electronic data in one or more communication networks. A collecting device collects credits related to the RECS certificates and a partializer partializes the credits on the basis of purchase orders received from green energy consumers. The current amount of credits purchased by the user is stored, with a deduction from the amount for the part of the credits based on the energy consumption that the user will derive from green sources.

WO 2016/110920 A1 relates to a power identification device comprising a "measured information acquiring unit" which acquires the amount of power generated by a power producer and the amount of power consumed by a consumer from a power generation unit and a consumption unit, at a predetermined period, as measured information. The purpose is to figure out, in real time, the actual supply of the power that has been purchased by a power consumer.

WO 2017/013982 A1 relates to a technology for certifying that a storage battery has been charged with green energy. A remote balancing device tracks energy put into a battery from either a collocated, "green", source or from the electrical grid.

Summary of the present invention

It is an aim of the invention to provide a system and method for generating electrical energy certificates (RTGOs), with which an improved matching of supply and demand of electrical
5 energy of a certain type, e.g. renewable energy, can be achieved.

This aim and possibly other aims are achieved by the invention as defined in the independent claims.

10 Embodiments of the present invention relate to providing methods, devices and systems for determining an operative state of an electricity distribution or supply network as well as computer programs for carrying out the methods. Embodiments of the present invention relate to methods, devices and systems for using an operative state of an electricity distribution or supply network in control of that network, e.g. in a remedial action as well
15 as computer programs for carrying out the methods. Embodiments of the present invention relate to methods, devices and systems for identifying origin of stored products created by use of electrical energy.

Embodiments of the present invention operate with real time GO (RTGO) certificates and
20 can provide one or more of :

1. Consumers have a way of checking that the energy they actually consume (consumed) was produced in a certain way using a certain technology for example it could be environment-friendly way, whether they buy GO certificates or not.
2. Energy producers can be incentivised by their consumers to switch to a type of
25 energy generation such as renewable energy, especially when these consumers buy GO certificates.
3. The locality of the origin and therefore also the transport of the energy from its source to the consumer are allowed to play a role in any transaction.
4. Motivate energy producers to further increase the fraction of one or more types of
30 electrical energy generation such as renewable sources.
5. Enable investment in storage technologies which are capable to store electricity produced in a certain way (typically in an environment-friendly way) at a certain moment in time which can be used at a later moment in time (typically when there is no wind/sun available)

6. Address at least one problem which can be dealt with by a remedial action.

An RTGO is produced synchronously with the consumption of the energy that it defines. RTGOs therefore represent recorded actual production and this production can be or is matched to recorded actual consumption. A sum total of RTGOs can not only represent an operative state of an electricity supply or distribution network or system but it can also provide a steering value in a control loop. The control must however allow for the steering value being latent, i.e. delayed. One solution to this delay of accurate knowledge of an operative state of the system is to provide a control loop which compensates for the delay, e.g. by forecasting and planning. Even without taking any delay into account a sum total of RTGOs gives a state of operations that can sufficient to demonstrate user appreciated goals. The RTGOs are useful in technical process of control of an electricity supply or distribution network.

Embodiments of the present invention provide a system and a method that can be independent from the technology used for generating electricity handling transactions or the presence or absence of a central authority. Embodiments of the present invention aim at a general RTGO system and enable the operative state of the system to be determined despite the increase in grid assets that are essential now and in the future for increasing the fraction of a certain type of energy generation such as energy generated from renewable energy sources.

Embodiments of the present invention can provide a system and method for operating the system and for determining the operative state of the system while creating and handling actual and effective energy production and distribution based on certified real-time attributes of produced energy e.g. including the origin of the energy and the method of the energy generation process used, e.g. generated with fossil fuel, nuclear, solar, hydroelectric, oil fired, coal fired etc.

Embodiments of the present invention propose a new system and method to determine the operative state of the system which provides energy production and distribution certificates that guarantee capture of an actual and real-time operative state of the system. Embodiments of the present invention enable real time determination of operative state based on energy production and consumption processes.

In one aspect embodiments of the present invention provide a computer based system for determining the operative state of an electricity supply or distribution network or system in which first energy deriving from renewable energy sources is introduced into the electricity supply or distribution network or system and consumed together with second energy produced by other sources, so as to be distributed therewith to predetermined consumer points in the electricity supply or distribution system or network, the first energy being associated to a guarantee of origin, whose economic value is proportioned to the first energy production over a limited time, wherein the amount of energy defined in a guarantee of origin is the amount generated in the limited time being a time period between five minutes and one hour, and the guarantee of origin disclosing a topological or topographical location at which the first energy was generated or the location within the electricity supply or distribution system where the first energy was injected into the electricity supply or distribution system or network, all of the guarantees of origin together defining and representing an operative state of the electricity supply or distribution system. As the energy is that energy that is generated in the time period of between five minutes and one hour, the RTGOs become available without delay. The location is preferably of the primary energy source such as wind, sun, fossil fuel, nuclear, etc.,

At least a control unit is provided, in association with the electricity supply or distribution network or system, adapted to manage computer connections over one or more communication networks.

Means for collecting electrical energy credits represented by the guarantees of origin can be provided as well as means for assigning credits on the basis of purchase orders received from one or more consumers of the first energy.

In a consumer point at least one consumption calculating device can be provided being capable of computing a total energy consumption in a plant served thereby.

30

Storage means for storing a number of credits and means for deducting from the number of credits a quantity of credits on the basis of corresponding first energy consumption by the plant can be provided.

The at least one consumption calculating device can be a smart meter, for example. The smart meter can be adapted to receive a guarantee of origin from the one or more communication networks.

- 5 A first energy production meter can also be provided.

One or more electricity storage devices for storing first energy in some form and being adapted to feed the stored first energy to the electricity supply or distribution system or network with an associated guarantee of origin. The electricity storage devices can be
10 batteries, pump storage means etc.

The smart meter can be adapted to measure electrical energy generated at a consumer point and to issue a guarantee of origin. The means for generation of guarantees of origin can be for energy production by CHP, gas or oil fired power stations, nuclear power stations,
15 hydroelectric power stations or similar.

A guarantee of origin of an energy quantity can be recorded in a distributed ledger, e.g. in a blockchain system. .

- 20 Any of ownership and energy source/type can be recorded in a distributed ledger.

The guarantees of origin can have a validity time so that they together define and represent a real time operative state of the electricity supply or distribution network or system.

- 25 The system can be adapted to perform one remedial action based on the operative state.

The operative state can include guarantees of origin generated with respect to first energy being generated at a topological or topographical location or a location within the electricity supply or distribution network or system on one side of a congestion.

30

The system can be adapted to carry out the remedial action by limiting electricity supply or distribution to electrical energy which has a guarantee of origin that reduces the congestion. The system can be adapted to reduce countertrading or redispatching.

The remedial action can be tracking volatility of renewable energy sources using the guarantees of origin or the remedial action can be delaying Grid Fortification.

5 In another aspect, embodiments of the present invention provide a computer based method for determining the operative state of an electricity supply distribution network or system in which first energy deriving from renewable energy sources is introduced into the electricity supply or distribution network or system and consumed together with second energy produced by other sources, so as to be distributed therewith to predetermined consumer points in the electricity supply or distribution network or system, the method
10 comprising associating the first energy to a guarantee of origin, whose economic value is proportioned to the first energy production over a limited time, wherein the amount of energy defined in a guarantee of origin is the amount generated in the limited time being a time period between five minutes and one hour, and the guarantee
15 of origin disclosing a topological or topographical location at which the first energy was generated or the location within the electricity supply or distribution network or system where the first energy was injected into the electricity supply or distribution network or system, all of the guarantees of origin together defining and representing an operative state of the electricity supply or distribution network or system.

20 The method can include managing computer connections over one or more communication networks, collecting electrical energy credits represented by the guarantees of origin, assigning credits on the basis of purchase orders received from one or more consumers of the first energy.

25 The method can include calculating in a consumer point a total energy consumption in a plant served thereby. It can include storing a number of credits and deducting from the number of credits a quantity of credits on the basis of corresponding first energy consumption by the plant.

30 The method can include storing first energy in one or more electricity storage devices and feeding the stored first energy to the electricity supply or distribution network or system with an associated guarantee of origin. To store the energy the method can include converting first energy to gas and associating a guarantee of origin with the gas. The gas

can be hydrogen, for example.

The method can include measuring electrical energy generated at a consumer point and issuing a guarantee of origin for that energy.

5

Generating guarantees of origin can be for energy production by CHP, gas or oil fired power stations, nuclear power stations, hydroelectric power stations or similar.

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A guarantee of origin of an energy quantity can be recorded in a distributed ledger, e.g. via a smart contract.

Any of ownership and energy source/type can be recorded in an RTGO in a distributed ledger.

15

The guarantees of origin can have a validity time so that they together define and represent a real time operative state of the electricity supply or distribution network or system. Real time means preferably aligned with balancing and/or trading timeframes.

20

The method can include performing one remedial action based on the operative state.

The operative state can include guarantees of origin generated with respect to first energy being generated at a topological or topographical location or a location within the electricity supply or distribution network or system on one side of a congestion.

25

The method can include carrying out the remedial action by limiting electricity supply or distribution to electrical energy which has a guarantee of origin that reduces the congestion or reduces countertrading or redispatching. The remedial action can be tracking volatility of renewable energy sources using the guarantees of origin or the remedial action can be delaying Grid Fortification.

30

In another aspect embodiments of the present invention provide a computer program product which, when executed on a processing engine executes method steps of embodiments of the present invention. A non-transitory signal storage medium can store the computer program product.

Embodiments of the present invention use Real Time Guarantees of Origin (RTGO) to determine the operative state at any time of the energy supply system and in real time by the validity of the GO only lasting for a very short period of time, typically 5 minutes or up to 15 minutes or up to 1 hour. Hence the GOs as used in embodiments of the present invention are called Real Time GOs or RTGOs. Also, any RTGO can optionally be coupled with the physical delivery of the electricity covered by the RTGO.

The RTGOs can certify additional aspects on the origin, including the time and period of generation, its location, etc. An RTGO can include an indication of a topological and/or geographical position in a grid especially the point of inserting the electricity into the grid. This indication can be used to decide whether the point of origin of the electricity is within a certain region or zone or not, e.g. on one side of a congestion. This indication can be used to calculate a penalty control value such as a nominal price for transportation over a distance from the point of origin and the point of consumption. Geographical proximity does not necessarily coincide with easy transport (e.g., when two locations are on opposite sides of a border between regulation zones), while topological proximity means that transport is simple, even if there is distance. Topological proximity usually determines the cost of transport of electrical energy. Geographical proximity can be important, e.g. if for example there is a need to know in which region the energy has been generated, e.g. on a side of a zone boundary.

RTGOs can have a validity period typically of 1 hour or less down to 15 minutes or down to a few minutes such as down to 5 minutes, typically aligning with the real time balancing or real time trading time frame of the grid.

Aspects of embodiments of the present invention can include one, some or all of the following:

1. the creation of a new type of certificates, "RTGO" that, compared to classic GO, certify the following additional aspects of the energy generated:
 - the short-term period in which the energy was generated. One-hour periods or less such as 5 to 15-minute periods are most useful. What is recorded in an RTGO is not a certain amount of electrical energy but rather how much electricity has been generated in a

fixed time. This allows a detailed and real time determination of the operative state of the system,

- an indication of the location at which the energy was generated: e.g. described in sufficient detail to guarantee that the system operator or every potential customer can easily check whether the energy generated can be (or has been) consumed from its connection point to the grid during the time of generation. To this end, the following will be sufficient in general for an RTGO:
 - the identification of the power generation facility
 - its geographic location (address + geographical coordinates) and/or its topological location in the grid, or
 - its injection point of electrical power into the electricity grid e.g. to which a consumer is connected.

Further aspects of embodiments of the present invention can include one, some or all of:

1. more aspects of the energy generated can be certified, including:
 - the percentage of generation sources involved in the generation of any or any combination of the following: hydroelectric, wind, wave, solar, bio mass, nuclear, CHP, gas, coal, fossil, geothermal etc.
 - other aspects, depending on their demand and utility
2. a near real-time understanding of the operative state of the system, where the certificates are delivered together with (or directly after) the delivery of the generated energy. This would allow energy traders to provide near real-time proof to their customers of energy usage,
3. a system and method that performs reliable, timely and automated (electronic) transfer of (at least parts of) an RTGO toward consumers. Consumers with storage capacity are then capable of generating and selling energy which is certified as created by a certain method - bought and stored earlier – at a time when the demand is higher.

Embodiments of the present invention have one, some or all of the following:

1. Do not rely on a specific ledger technology (e.g. blockchain) even if this technique can be used with embodiments of the present invention.
2. Do not focus on energy transactions and are in fact completely independent of how energy is transmitted or traded.

3. Can be used with a solution for active grid management (e.g. energy balancing, or congestion management) and can in fact be completely independent of how energy is balanced and congestions are prevented or solved. However, the RTGOs can be used to solve a congestion problem or other problems requiring remedial action.
- 5 4. They do not rely on secure storage of complete ownership records (e.g. history of certificate ownership).

Embodiments of the present invention can have one, some or all of the following advantages:

- 10 • Making the RTGOs electronic (e.g., using blockchain / distributed ledgers, using other, non-distributed ledgers, using a central certificate agency, etc.)
- Creating a (web) service that enables world-wide (or EECS wide) (automatic) verification of the RTGOs.
- A system and method to split up RTGOs into finer parts (IOU), and a system to
- 15 combine RTGO parts acquired into a full RTGO, aggregating over time and/or over energy sources.
- Delivering RTGO (or a partial RTGO) at near-real-time, immediately after the RTGO has been generated.
- Real-time exchange of RTGOs
- 20 • Identifying and including further aspects of electricity generation (e.g. emerging technologies, plants that receive / do not receive subsidies, etc.)

Brief Description of the drawings

Figure 1 illustrates an electricity supply or distribution network with which embodiments

25 of the present invention can work.

Figure 2 shows an embodiment of a measuring and recording device.

Figures 3 and 4 show how countertrading for mitigating congestion at a coupling is required and can be avoided with embodiments of the present invention. .

Figure 5 shows a main congestion site in 2017 and newsouthwest coupling.

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Definitions

RTGO validity period.

The time span for which any single RTGO is valid. As in embodiments of the present invention the RTGO must reflect the current operational state of the grid's power mix, this period should be short, e.g. compared to the time intervals used in power related contracts within the respective grid. In embodiments of the present invention a maximum validity period is between 15 minutes and one hour. Each RTGO is created for the interval in which the RTGO remains valid.

Energy amount of a single RTGO.

Current GO schemata consider one MWh as the amount of energy for every single energy certificate. For RTGO this quantity can be variable and can reflect the energy produced by a single installation (e.g., one wind turbine) over the specific interval for which the RTGO is created. This is within the range of 5 minutes to one hour.

'Registering' means that the values measured are stored with time stamps.

The words **'authenticity', 'integrity', and 'availability'** are well defined terms in the field data and information security, together with **'confidentiality'** they form the CIAA extended triad of Information Security. Note that confidentiality does not have to be guaranteed. Also note that authenticity and integrity are guarantees mainly in the interest of the consumer, while availability is primarily in the interest of the producer.

"Renewable energy sources" include one, some or all of :

Sources using solar power such as Solar – PV and Solar-thermal

Sources using wind power such as wind turbines

Sources using any form of biomass to generate electrical power

Hydroelectric electric power sources

Tidal power sources

Wave power sources.

Geothermal power sources such as deep geothermal or flat geothermal sources may be considered as "renewable".

“Global warming reducing sources” may include one, some or all of:

Sources using solar power such as Solar – PV and Solar-thermal

5 Sources using wind power such as wind turbines

Sources using any form of biomass to generate electrical power

Hydroelectric electric power sources

Tidal power sources

Wave power sources.

10

Global warming reducing sources are considered as a subset of renewable energy sources so that reference to renewable energy sources automatically includes global warming reducing sources.

15 **“Real time”** in the context of the present invention refers to a time less than a typical dynamic change of load or generation of electrical power. Hence real time can be one hour or less, e.g. down to 15 minutes or down to minutes such as 5 minutes. Real time means that the process continues without delay, i.e. that an analysis is carried out and is available as soon as the events which are to be analysed are available. Real time also preferably
20 means that the time period over which energy is supplied and recorded in an RTGO is aligned with balancing and/or trading timeframes.

“Countertrading” is a measure for mitigating potential congestions – called a ‘remedial action’ in the European Commission Regulation (EU) 2015/1222 of 24 July 2015, Article
25 2(13) – within the coupling of two regulation zones. European Commission Regulation (EU) 2013/543, Article 2(17) defines countertrading as follows:

“countertrading” means a cross zonal exchange initiated by system operators between two bidding zones to relieve physical congestion.”

30

“TSO” is the Transport System Operator – The entity responsible for operating the high voltage (HV) transport grid of a regulation zone. Transport System Operator is usually the operator of a High Voltage, HV transport grid, usually identical with the regulation zone responsible.

“**Tractability**”, mean providence information from the electricity generation to its consumption.

- 5 This is in contrast to the **DSO** (=Distribution System Operator) which operates one or multiple medium to low voltage grids (MV, LV), i.e., grids that distribute electricity to consumers.

“**Remedial Action**” can be described as any measure applied by a Transmission System
10 Operator (TSO) or several TSOs, manually or automatically, in order to maintain operational security, as well as to relieve physical congestion on their electricity supply or distribution networks.

“**State**” of an electricity supply or distribution network or grid can be for example:

- 15 a) Not all RTGOs are used within their validity periods – caused by too much renewable energy being supplied. Reaction - activate electricity storage.
- b) Not all RTGOs are used within the validity period. Power that has not been consumed would have been curtailed. The following can be adopted:
- 20 (i) The power represented by the leftover RTGO has been consumed but the parallel purchases of RTGO were not done. In this case a trade can still be made, or
- (ii) There would have been too much power in the system and the generation represented by the RTGO was curtailed, however in this case the RTGO would
25 have been created in first place.
- c) All RTGOs used but more could have been used – caused by low output of renewable energy sources. Recover renewable energy from storage or bring more renewable sources into operation on the grid and/or predict supply and control the demand.

30 **Description of the preferred embodiments**

The current tracking system of attributes for electricity generation includes Renewable Energy Certificates (RECs) and the Guarantee of origin (GO) extensions which are

delivered to the consumer in parallel to the physical delivery of the electricity. The present (current in 201) GOs are;

- For 1 unit of electricity of 1 MWh
- Valid for 1 year
- 5 - Can only be used once as an electricity attribute
- Informative on the source of the unit of electricity

But,

- it can be transferred, independently of the energy to which it relates (it is not coupled
10 to the energy unit that has been produced). Consequently, 100% nuclear energy can be sold as green energy if REC/GO for the same amount of energy is purchased.
- The real-time availability and intermittent character of the renewable energy source is completely hidden for the consumer (being valid for 1 year).

15 Hence, with the current system, it is not possible to identify;

- An electricity supplier who only buys GOs on the market
- An electricity supplier who is actually investing in renewable energy resources
- An electricity supplier who is investing in infrastructure to cope with the
intermittent character of renewable energy (e.g. Battery technology)

20

To address these problems embodiments of the present invention are directed to a novel type of extension for the RECs, and compared to the existing GOs the Real Time Guarantee of Origin (RTGO) differs in;

- Having a shorter validity term, preferably from 5 or 15 min to 1 hour, having the
25 advantage of resembling the real-time production of the renewable energy or global warming reducing energy sources. This contributes to the determination of a real-time operative state of the system from the sum total of valid RTGOs.
- An indication of a topological position of a generator in a grid and/or an indication of a geographical position in a grid of a generator so that a value for transport of electricity
30 between a generator and a consumer can be calculated using this indication. Preferably, where there are multiple regulation zones, it should be possible based on the indication to determine in which regulation zone a generator is located. This can be used when there is congestion between two regulation zones, for example. This is an example of the use of topological proximity in some or all embodiments of the present invention, being coupled

with the physical delivery of the electricity, thus resembling the ‘real-time’ delivery of the electricity to the grid. This also contributes to the determination of the real time operative state of the system from the sum total of RTGOs.

- 5 An RTGO preferably has a unique indicator to distinguish it from any other RTGO.

An RTGO can be used with a “price” for the electrical energy defined by the RTGO. This price of electricity is not an attribute of an RTGO (e.g. there is no need for a price value in an RTGO) but can be used to control operation as part of a system governed by supply and
10 demand. This “price” is not a price that is charged to a consumer as such a price may vary a great deal. Instead the “price” is used as a parameter for influencing decisions. Hence, this “price” can be a control variable. E.g. a control variable in systems or markets. Such a price used as a control variable can be adjusted to include a value for having a local value chain, include a value if renewable e.g. “green sources” are used and/or transport cost,
15 and/or technology selection, etc.

An RTGO may be formulated as a smart contract in a blockchain system of distributed ledgers, or the information in an RTGO may be used as an input for the operation of a smart contract in a Blockchain system of distributed ledgers.

20

RTGOs can be recorded during generation of any electrical energy generated by renewable or global warming reducing energy sources. Optionally, RTGOs may also record other energy sources such as energy generated by fossil fuel or nuclear power stations, by brown coal power stations. Embodiments of the present invention using RTGO can track all
25 energy generated, hence embodiments of the present invention can determine an operative state of the system, e.g. determine the current energy mix. Proponents of nuclear energy may equally benefit from RTGO as proponents of green energy and the use of brown coal plants can be monitored. Hence embodiments of the present invention can track electrical energy generated with two or more different technologies.

30

RTGO are not restricted to any specific form of energy production. There is no intrinsic bias as to what energy sources are preferred. So an RTGO can record electrical energy generated by renewable or global warming reducing energy source. Other RTGO can record energy from other energy sources such as energy generated by fossil fuel power stations.

Thus, an RTGO may record energy generated by a first type of energy source such as renewable or global warming reducing energy sources, or optionally, an RTGO may also record a second type of energy sources such as energy generated by fossil fuel power stations. It is included within the scope of the present invention that RTGOs can record energy generated by a plurality of types of energy sources. For example, one RTGO can be for renewable energy sources a second for global warming reducing energy sources and a third for energy from fossil fuel power stations.

Embodiments of the present invention can be applied to a power system 40 shown schematically in Figure 1 where there are different producers 42, 43, 44 and consumer devices 7 on consumer premises or clusters 45 of consumer devices 7 on consumer premises which generate or consume electric energy, and which are coupled through an electricity supply or distribution network 41. High or medium voltage producers 42 or medium voltage produces 44 can be producers generating electricity using fossil fuel power stations (coal, gas or oil fired for example), or nuclear power stations but renewable energy generators are preferred such as solar power, hydroelectric, wind turbines, etc. or by global warming reducing sources. There can also be low voltage producers 44 such as from domestic solar panels. Producers 43 can use conventional power plants such coal, gas or oil fired power stations, or nuclear power stations or optionally geothermal power stations. This electricity supply or distribution network 41 allows for generation and transmission of electric energy between consumer devices 7, and clusters of devices 45 and producers 42, 43, 44 and can include a central control unit 46 for controlling operation of the electricity supply or distribution network 41. There can also be local control units 47 which control a consumer device 7 or a cluster control unit 49 for controlling a cluster 45 with consumer devices 7.

The different producers 42, 43, 44 consumer devices 7 or clusters 45 of consumer devices 7 on consumer premises, the central control unit 46, the cluster control unit 49, the local control units 47 are coupled together by means of a signaling telecommunications network (not shown).

Hence the control in some embodiments can be centralized in a central control unit 46 or in some embodiments can be distributed among local control units 47 or cluster or regional controllers 49. A cloud control unit 48 may be located in the "Cloud" 50 which is also part of the telecommunications network linking all generators and consumers. The central

control unit 46 may be located in a server which is part of the telecommunications network linking all generators and consumers. Any of the controllers 46, 47, 48, 49 can operate a feed forward control such as a 24 hour in advance of use feed forward controller. In such a system the requirement for supply or consumption of electrical energy can be predicted in advance for example 24 hours ahead for example. The prediction may be static, i.e. reliance is made only on a prediction in advance such as 24 hours in advance or the prediction can be dynamic starting for example on a prediction in advance such as 24 hours in advance, followed by update requests for more or less electrical energy.

10 The predictions may be based on a model of the grid. For example firstly measurements of the grid are made now to determine its state and the model is used to predict the operative state of the grid at a future date like tomorrow. Methods of predicting the generation of electrical power by energy sources are known to the skilled person, see for example “Netzlastproblematiken im europäischen ENTSO-E Netz in Hinblick auf den bestehenden
15 “regerative-Energien-Kraftwerkspark”, GRIN Verlag GmbH, 2013, ISBN 978-3-656-51308-7, and/or “Analysis of cross-border congestion management methods for the EU internal electricity market”, final report 2004, European Commission.

The mathematical models used by the feedforward control system may be created and input or it may be learned by the control system. Hence the control system can be capable
20 of learning and/or adapting any mathematical model by learning, e.g. by machine learning techniques.

In particular, transport system operators (TSO) that are responsible for the regulation zones (RZ) can use a model of the grid to predict congestion problems. In the case of the congestion of the coupling this model can include predicting the net power flow over the
25 coupling lines. This has also to be for all neighbouring regulation zones. Learning however is not necessary. The grid is known and can be described and for predicting of the volatile consumption, proven statistical methods can be used.

In accordance with embodiments of the present invention, feedforward control can integrate a mathematical model into the control algorithm such that it is used to determine the control
30 actions based on what is known about the state of the system being controlled. For example a TSO can calculate the expected power flows from a model of the grid.

For example, ideally, at all times during operation of such a power system 40 there needs to be a balance between production and consumption. Currently the main control paradigm is that production follows consumption. This can be no longer efficient for mainly two reasons. Firstly, with a continued integration of renewable energy, these balancing requirements become more demanding in terms of energy, power and ramp rate or at least ramp up/down. Handling this is inefficient as it requires ramping (up/down) of mainly gas fired power plants which have unfavorable energy efficiency (primary energy to practical energy). This results in excessive energy consumption and pollution. Secondly, the balancing assets are mainly connected to the high voltage electricity supply or distribution network, whilst renewable energy generators 42 are often located at the low and medium voltage level causing local voltage and congestion issues, and which requires local flexibility to solve these. For both issues, operating according to the electric consumption instead of production can provide part of the solution as demand flexibility is abundant and efficient in terms of energy and pollution, furthermore it is connected to both high and low voltage levels. Embodiments of the present invention can be used in the control or operation of the consumption of energy such as electricity of large heterogeneous clusters of consuming devices which exhibit some flexibility, i.e. having the freedom to adjust the usage of energy over time. The usage of energy over time may be predicted using feed forward control, e.g. using a static prediction in advance such as 24 hours in advance or a dynamic prediction, e.g. using a prediction in advance such as 24 hours in advance followed by updates to the prediction up to the time of generation. The predictions can be adapted the closer the system come to the time in advance for which the first prediction was made. In these predictions renewable or global warming reducing energies can be taken into account. For example, TSOs can include these by utilising a higher priority for these. Predictions can be static or dynamic. Demand can be predicted on the TSO level by simply using statistics and hence would be static.

Predicting production from renewable sources is more complex, and such predictions (e.g. forecasts) are normally dynamic.

As a further example, there is a preference for setting a higher priority for renewable energy sources in most jurisdictions in Europe. However, where this is not practically possible (e.g., where an inflexible base production of a coal plant cannot be reduced) curtailment still occurs.

The electricity supply or distribution network 41 can be coupled to other consumers, such as industrial users and offices, and electricity supply or distribution network 41 can be coupled to other electricity supply or distribution networks.

- 5 Any, some or all of the central, cluster or local or cloud control units 46, 49, 47, 48 or measuring and recording device 9 can be connected to, or can include a power or energy sensor (e.g. kWh-meter) which determines the power usage and preferably is adapted to save historical records of energy used by each device 7 or cluster 45. Any, some or all of the central, cluster, local, or cloud control units 46, 49, 47, 48 can include a measuring and
10 recording device 9 according to the present invention.

In order to ensure that a consumer device 7 consumes only electrical energy generated by a renewable energy source or a global warming reducing energy source, use can be made of the measuring and recording device 9.

15

- Measuring and recording device 9 is adapted to read RTGOs made during generation of any electrical energy generated by renewable, global warming reducing or fossil fuel power stations. The measuring and recording device 9 may declare consumption of electrical energy in accordance with an RTGO. If this is done no other measuring and recording
20 device 9 may use that RTGO.

- A consumer device or some consumer devices 7 can consume electricity but also can generate it (e.g. by means of solar panels). A consumer device or some consumer devices 7 or a measuring and recording device 9 or a central controller 46 or a local 47 or cluster
25 control unit 49 or a cloud control unit 48 can be adapted to generate an RTGO for all electrical energy that is generated. For this purpose the consumer device or some consumer devices 7 or a measuring and recording device 9 or a central 46 or local 47 or cluster 49 or cloud 48 control unit can include a processing engine such as a microprocessor with volatile and non-volatile memory or can be connected to a computer which produces certificates in
30 electronic form that represent the exact quantity of electrical energy produced during the respective time interval that is specified for recording in RTGOs for the production of the electricity. The RTGO system according to embodiments of the present invention issues an RTGO with an arbitrary quantity of electricity generated in a fixed interval at a fixed point in time. Example: If in a given time interval from $t_0 - 15$ minutes to t_0 , 456826.635Wh

were produced by installation *A*, then an RTGO over the exact amount of 456826.635Wh is generated at time t_0 . This electricity could be generated by wind turbine generating renewable electricity. The smart meter of a customer can register an electricity consumption of 1153,532Wh. The smart meter can accept/cancel 1153.532Wh of the RTGO and
5 456826.635-115.532 = 455673,103Wh is still available for other customers.

RTGOs according to embodiments of the present invention are issued for an arbitrary quantity of electricity at a fixed point in time. E.g. in the last 15 minutes a PV system produced 2635,532 Wh of energy with a to be defined resolution. There is synchronicity
10 between the generation and the consumption of energy. Energy certified by an RTGO is consumed at the point when the RTGO is issued. The electricity associated with an RTGO can be acquired, i.e. bought whole or in part by a consumer and matched up with the consumed energy.

15 This cancelling of recorded production with recorded consumption is made in hindsight. The information about the energy being produced through appreciated means is latent at the time of consumption.

Preferably these RTGO are certificates in electronic form.
20

All RTGOs in electronic form can be recorded at a local or cluster control unit 47, 49 or can be sent to a central control unit such as control unit 46 or to a cloud control unit 48 through the telecommunications network, such as the internet. Information that any valid RTGO has been accepted and consumed can also be recorded at a local or cluster control
25 unit 47, 49 or can be sent to the central control unit such as control unit 46 or the cloud control unit 48 through the telecommunications network. A generator in the electricity grid generates electrical energy based on an elapsed time and not on an amount of energy. It then issues a RTGO and at another location in the grid, the digital meter (e.g. a smartmeter) of a customer registers a certain amount of electricity consumption.

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It is preferred for this purpose for the consumer device or some consumer devices 7 or a measuring and recording device 9 or a central 46, or local 47 or cluster control unit 49 or cloud control unit 48 to be continuously connected to the telecommunications network.

- After a number of RTGO have been generated and stored in an archive such as a central archive, it is necessary for the consumer devices 7 to match its received electricity against RTGO synchronous to the consumption. The sum of the RTGO valid for a given time period for energy generated by renewable energy power stations and/or for energy generated by global warming reducing power stations and/or for energy generated by fossil fuel power stations reflects the operative state of the electricity supply or distribution network of that time period.
- For forecasting and other potential data science applications, the total sum of all currently valid RTGO can be used. To make a more detailed analysis the RTGO may be archived or saved in subcategories e.g., all RTGO from a photovoltaic generator in a certain region A, and/or all RTGO from wind turbines in a certain region B. The granularity of the RTGO determines the accuracy of RTGOs being able to reflect an operative state of the electricity supply or distribution network and importantly to reflect an operative state in “real time”, i.e. per validity time period.

- It can be important for a consumer to know if any valid RTGO has been used to generate energy supplied to the consumer in the past. The consumer device or some consumer devices 7 or a measuring and recording device 9 or a central 46, or local 47 or cluster control unit 49 or a cloud controller 48 may be adapted to provide answers to consumer questions like, “should I consume now, or at other times?”. This question can be answered based on the RTGO and local intelligence available in a measuring and recording device 9 or a central 46, or local 47 or cluster control unit 49 or a cloud controller 48 at any level of sophistication such as planning, forecasting, etc.

- All electricity that is generated within a 5 up to 15 minute up to one hour temporal validity of an RTGO will be consumed. Electricity that will not be used will have to being consumed.
- If an RTGO is issued, then the electricity is actually fed into the grid, and a user consuming this electricity has the option to purchase the RTGO. If the RTGO is not sold, another user might have consumed the electricity as grey electricity of unknown origin. There is no intrinsic need to curtail for example an electricity provider of one type of electricity (e.g. renewable) only because the corresponding RTGO was not sold.

The system and method of RTGOs according to embodiments of the present invention allow a near real-time determination of the operative state of the system for the delivery of electricity generated by one or more means. For example, an RTGO may certify electricity
5 from a nuclear power station if this is desired. The use of RTGO is independent of technology used to generate the electricity.

Or the RTGO may certify renewable energy has been used for generation, since the certificates are delivered together with or directly after the delivery of the generated
10 electricity. This would for example allow consumers who invested in renewable energy sources and battery technology to deliver and sell RTGO certified electricity.

RTGO are issued per time interval over the amount of energy produced by a single plant with homogeneous properties. The precision can be adjusted but is preferred to be in the
15 sub-Watt-hour range. A higher precision provides the system with a finer granularity. Note that previous GO had a fixed amount of energy through a variable time interval, while RTGO have a fixed time interval representing the actual, concrete, amount of energy produced.

Figure 2 shows an embodiment of a measuring and recording device 9. Such a device can be located at a consumers premises like a house 10. Such a domestic house 10 can have solar panels 14 and can function as a low voltage generator and the current can be injected
20 into the grid 12 via an inverter 13. Such electricity generation can generate an RTGO based on the electrical energy which has been generated over a time period such as 5 minutes to 1 hour. The preparation of the RTGO can be carried out by a meter such as a smart meter
25 11 optionally with the assistance of a computer 17 connected to a telecommunications network 19. The RTGO can be sent by the smart meter 11 and/or the computer 17 over the network 19 to one or more of the controllers 46, 47, 48, or 49.

The house 10 may also receive electricity from the grid 12 to drive various appliances in the house 10 such as a washing machine, television, boiler, refrigerator, hot plate and/or lighting and this electricity may be recorded in an RTGO which can then be stored locally
30 in the computer 17 and/or the smart meter 11. A display 15 can be provided as part of the computer 17 which can be programmed to display an operative status of the locally stored

RTGOs. Alternatively the same information may be stored on a server on network 19 or in one of the controllers 46, 47, 48, or 49. Where all RTGOs are stored centrally in the system such as in controller 46, then provision can be made such that operators (e.g. a TSO) and/or consumers can view the operative state of the electricity supply or distribution network based on the recorded RTGOs.

In the following embodiments of the present invention are described which provide remedial action utilising RTGOs.

10 Remedial action such as avoiding countertrading

Countertrading is applied in a situation where cross regulation zone energy trade, which could be predicted, for example, by means of the model based methods for day ahead feed forward dynamic load flow control as employed by a TSO , threatens to cause congestion in the coupling between the regulation zones. In Figure 3 consumers ((1), (2), (3)) within a regulation zone A demand a total amount of energy produced in regulation zone B that will lead to a congestion within the coupling between regulation zones A and B. This is the result of operating multiple, mutually independent, consumers and generators whereby no single activity can be identified as having caused the congestion. The result of the planned activity will be that energy providers in regulation zone B will increase electricity production so that a congestion within the coupling will occur. Countertrading measures are illustrated in Figure 4. The TSOs of regulation zones A and B together plan to obtain energy from regulation zone A and employ negative reserves of the same amount in regulation zone B in order to reduce the power flow over the coupling and avoid congestion.

Note that in countertrading, no concrete intervention takes place in the power output of any specific plants, instead regulation-zone spanning bids on the energy market are used to motivate/encourage a mitigation of the congestion. Countertrading thus can only be applied where the network topology does not require very specific producers or consumers to increase or decrease their input or output.

The operators of regulation zones A and B share the cost of the countertrading measure. This entails compensation for producers in zone A for increasing production (Figure 4; (a), (b)) as well as compensation for producers in zone B for reducing production ((e), (f)). The

measure does not entail identifying or attempting to identify the root causes for the congestion (e.g., by identifying energy consumers in regulation zone A or producers in regulation zone B that ultimately caused the imbalance). Consequently, the producers in regulation zone B that are paid to reduce their production may or may not be the same producers whose production contributed to the original congestion (see Figure 4 (d), (f)). Conceivably, even consumers in regulation zone A that contributed to the original congestion might participate in the countertrading measure by offering load shedding (not shown in figure), receiving overcompensation for (partially) rolling back on an original plan.

Countertrading is necessary within the liberalized energy market mostly because information about the location of generation or consumption of energy is ignored in the original planning efforts. The entity requiring electrical energy does not know which specific plant will produce the requested energy. This is also the reason why the expenses that occur in protecting the couplings from congestions cannot be relayed to the parties involved in the cross regulation zone trade.

Note however that the choice of countertrading as a mitigation for the potential congestion presupposes that the respective energy demands of regulation zones A and B actually can be mostly covered within the zones themselves, or at least with no more than acceptable power flow over the coupling.

In this embodiment of RTGOs, even when these are applied in conventional power generation, expose the necessary location information which is a mandatory part of the information content of an RTGO. Using (potentially extended, forward) RTGO-based operation, a consumer among (1), (2), or (3) in regulation zone A will be able to calculate closer topological or geographical distances for transport of energy from plants within regulation zone A (e.g. (a), (b), or (c)), while the energy from assets within regulation zone B ((d), (e), or (f)) will include larger topological or geographical distances (resulting in higher transportation costs and an insurance for potential congestions within the coupling). In effect, using the information in RTGOs the additional cost of countertrading for the TSO would be avoided, as the pricing differences that may have led to a cross regulation zone trade would be leveled to a point where congestion is highly unlikely (and, if congestion still occurs, it cannot be solved with countertrading, as the root cause is not a simple pricing

difference). Note that grid fortification efforts will be channelled towards the technically necessary demands.

5 The system may impose use of RTGO information to avoid countertrading. Instead of relying on the indirect interest in short transport distances, the system may obligate any consumers to use an energy source that is in the same region as the consumer is located. This imposition may be limited in time, i.e. until the congestion problem no longer exists. The topological or geographic location information in an RTGO can indicate to a potential consumer in which region an energy source is located. Hence, this information can be used
10 to select energy sources from within one region.

Further Remedial Actions

Further Remedial Actions may include, but are not limited to the following:

15

Re-dispatching: embodiments using RTGOs can alleviate a redispatch measure. The necessity for redispatch can be avoided through a better exploitation of the currently available renewable or global warming reducing power.

Demand Side Response

20

Embodiments utilising RTGO can assist in demand side management (DSM) or demand response. For demand response / DSM the problem exists of the volatility of renewables on one side and the lack of information about the volatility on the other side. Embodiments
25 utilising RTGO have a power consumption schedule that follows the volatile provision more closely.

Delaying Necessity for Grid Fortification

30 Embodiments utilising RTGO can assist in topology changes in an electricity supply or distribution network. Embodiments utilising RTGOs have information within themselves of time/location and hence a state of the electricity supply or distribution network can be derived based on the use of a currently available infrastructure as well as steering the planning and building of new infrastructure as described below.

An important topic within the grid infrastructure is the necessity for transport grid fortifications and additional lines that are made necessary by a more diverse yet currently location agnostic market. Installation of view electricity lines can face significant resistance
5 due to, for example, opposition based on the accusation of landscape abuse.

For example, the site in Germany with the highest amount of congestion problems in 2017, was the coupling between Remptendorf in Thuringia within the regulation zone of 50Herz, where the lines from the brown-coal burning plants Jänschwalde, Schwarze Pumpe, and
10 Boxberg in East Brandenburg and Saxony, the lines from the coal-burning plant in Lippendorf near Leipzig and the transport lines towards the north from Leipzig and Erfurt come together, and Redwitz in Bavaria within the TenneT regulation zone, where the lines divide in direction of the grid node at the old nuclear site in Grafenrheinfeld and the metropolitan area of Nuremberg in the west and the Franconian region in the east (Figure
15 5 item (a)). According to the “Quartalsbericht zu Netz- und Systemsicherheitsmaßnahmen – Gesamtjahr und Viertes Quartal 2017” cited above (pp. 17ff), 1,791 hours of redispatch measures were necessary at this site, with an equal volume of feed-in reductions and feed in increases of 2,455 GWh each. Only the opening of the southwest coupling (“Thüringer Strombrücke”) in the fourth quarter of 2017 reduced the number of congestion incidents at
20 the site (Figure 5 item (b)).

This new coupling, which provides a stronger link to the brown-coal burning plants mentioned above, was mostly justified with eco-friendly wind-generated power from the Baltic and North Sea. Upper Franconia however is a major producer of renewable energies
25 (mostly wind and solar, but also biomass).

In a further embodiment of the present invention the information in the RTGO can be used to accept and utilise energy that has been generated in certain geographic regions. For example, use of RTGOs can allow energy from the energy-rich region Baltic and North Sea
30 and Upper Franconia, to be better employed for supplying the Nuremberg metropolitan region and potentially avoiding a large part of the congestions in Figure 5 (a), reducing the need for the southwest coupling Figure 5 line (b).

In contrast thereto, information in the RTGO can be used to determine an operative state of an electrical supply system in order to highlight where there is congestion which cannot be mitigated without additional lines.

5 **Metering components**

Supply side

Each electricity producer 42, 43, 44 is must be equipped with a suitable, registering, metering installation that tracks the power and energy fed into the electrical grid. An example is the measuring and recording device 9. Preferably, the metering installation e.g. measuring and recording device 9, control unit 46, or 48 or 49 is capable of delivering the measured values in a secure way that guarantees authenticity, integrity, and availability of the data to a data processing /computing system in strict real time (i.e., with real-time guarantees that are significantly smaller than the projected validity period of an RTGO). Preferably, the metering installation should further be capable of storing the measured values for an appropriate period of time together with absolute timestamps for each piece of information in a way that guarantees authenticity, integrity, and availability to allow for an a posteriori inspection of the data (legal tractability) and to resolve payment disputes.

Consumer side

The measuring and recording device 9 or the local control unit 47 or cluster control unit 49 can be a smart meter. Due to the roll-out of smart meters, it is possible to measure the electricity consumption of residential customers with a high resolution in time. The combination of a smart meter and RTGO make it possible to verify in real time whether the received electricity is from a renewable or global warming reducing electricity source. If energy contracts with consumers indicate a minimum amount of real time renewable or global warming reducing energy, the analysis of the complete set of still valid RTGO provide a real time operative state of the system.

Consumer devices 7 can be equipped with a metering installation such as the measuring and recording device 9 that tracks power and energy consumed from the grid (not shown – see later). The metering installation such as the measuring and recording device 9 is preferably connected to the telecommunications network in a way that allows to

communicate the measured data in a secure way that guarantees authenticity, integrity, and availability as well as strict real-time communication (i.e., with real-time guarantees that are significantly smaller than the projected validity period of the RTGO). Also likewise, the metering installation such as the measuring and recording device 9 must further be
5 capable of storing the measured values for an appropriate period of time together with absolute timestamps for each piece of information in a way that guarantees authenticity, integrity, and availability to allow for an a posteriori inspection of the data and to resolve payment disputes.

10 **Information technology and communication components**

Production side

A computing system is preferably connected to the metering installation at the supplier side. The computer system preferably processes the measurements in a secure way, guaranteeing
15 authenticity, integrity, availability. The processing comprises: accumulating of power and energy values over the defined interval. An RTGO is produced for each electricity generator at each time interval, e.g. 5 up to 15 minutes or to one hour. The amount of energy for the RTGO is the amount of energy produced by the generator in that interval (in contrast to conventional GO that are created for each MWh of energy independent from the period of
20 its generation).

The data captured by the RTGO in addition to the energy amount (producer, location, primary energies, etc.) is preferably mandatory for the RTGO.

25 **Equipment of the newly produced RTGO certificate with a globally unique identifier.**

Global uniqueness can be easily achieved with hierarchically layered identifiers in a similar way as IP addresses.

Securing of the uniquely identified RTGO with a cryptographic signature/credentials.

30 The signature guarantees at least authority, authenticity, and integrity of the contained information and allows for a posteriori legal tracking.

Provision of the uniquely identified and secured certificate to an open marketplace.

Once created, an RTGO certificate is offered in an appropriate marketplace.

Consumption side

A computing system integrated into or connected to the metering installation such as the measuring and recording device 9 at the consumer side preferably processes the measurements in a secure way, guaranteeing authenticity, integrity, availability. The processing consists of or comprises the following steps.

Accumulation of power and energy values over the defined interval.

The actual consumption is tracked and accumulated over the given interval.

Identification and purchase of matching fractions of offered RTGO on the marketplace.

According to the amount of energy consumed and the consumer appreciated goals (selection criteria), an RTGO, a fraction thereof, or a number of (fractions of) RTGO that together match the consumption is selected and purchased from the marketplace. Each (fraction of an) RTGO can be sold only once and needs to be cleared with the consumed amount of energy.

Self-certified logging.

The purchased (fractions of) RTGO are stored together with the consumption data in a secure way to allow for later inspection. The reports can be provided in real-time.

Market place(s)

At a network location accessible to both the supplier side and consumption side computing systems there must be one or more computing systems running a (distributed) market place that can collect offered RTGOs from suppliers and sell them to consumers. It must ensure that each (fraction of an) RTGO is sold exactly once and met with an amount of consumed energy as reported by the buyer. Also as an alternative RTGOs can be delivered “over the counter”. A “trusted” party or a distributed secure system (e.g. blockchain smart contract and the like) that ensures that an RTGO or a part of an RTGO is only transferred once.

Logical components

Certificate authority or distributed ledger

Embodiments of the present invention provide a system and method that requires authentication, authorization, protection of data integrity as well as protection of privacy (confidentiality of purchase operations) in various places of the operation.

5

Integrity, authenticity, and availability of measurements between the measuring installation and the respective consumer or supplier side computing system processing the data can easily be established through the use of a direct cable, dedicated network, or private network section. Secure user management and virtualization based security or dedicated
10 secure devices are recommended for the first level processing of the measurement data. Authentication between these (usually collocated) machines can be achieved through pre-shared keys.

A global trust mechanism is important where the marketplace is involved. The marketplace
15 requires a mechanism for checking the uniqueness of each certificate, avoid double sales or double purchases, and check the authority of each market participant.

To manage the trust within the marketplace and among the participants a central, trusted, certificate authority *or* a distributed, cryptographic, ledger (blockchain) can be used. If the choice is for a distributed ledger, it is important that a Byzantine agreement method other
20 than proof of work is employed.

Whether a central authority or a distributed ledger is used for securing and authenticating the transactions is orthogonal to the question whether a central or a distributed market is used.

25

Attribute selection and labelling**Information contained in an RTGO.**

To reflect the actual operational state of the grid, an RTGOs information preferably
30 contains:

- The amount of energy contained,
- The type(s) and amount of primary energies used,
- The location of the production plant (e.g. in the form of a topographical or geographic location information), and

- Name/company/legal entity of the producer.
- Optionally a “grid identifier” to identify to which grid a generator is attached.

User interface at consumption side.

- 5 At consumption side there is preferably an access for the user allowing to select any criteria or group of criteria and set levels of appreciation (e.g., mandatory, preferred, disfavored, excluded). The criteria can be linked with topics/themes (e.g., green energy, regional value chain, least transport, etc.) and be accessed through feature models and presets. Access through a telecommunications network or mobile devices with appropriate authentication
- 10 and access control, graphic interfaces and reporting are desirable.

The criteria setting governs the matching process within the consumption side processing and the interaction with the marketplace.

15 Enhancements within the information technology components

The present invention includes within its scope correlated data use, forecasting, reporting, adaptive behaviour, categorizing, tractability, locality, and transport as described below.

Correlated data use for additional operative purposes

- 20 With the availability of mechanically leverageable information about the current geographical distribution of energy input into the grid to every consumer, our system and method allows to introduce a technical and/or economic incentive towards proximity. Combined with the layout of the transportation / distribution grid, TSO (transmission system operator) and DSO (distribution system operator) can optimize routing of the energy
- 25 and work towards a higher and more even exploitation of the grid assets.

Forecasting

- Both the supplier and the consumer may employ forecasting technologies to advertise availability of electricity with specific attributes ahead of time as well as to better plan
- 30 consumption optimized towards the consumer appreciated goals. Reservation of RTGO prior to their creation is possible and will increase the degrees of freedom for optimization. Alternative communication channels that bypass the marketplace can be employed to provide forecasts.

Reporting

Consumers can interface with their control system to learn where exactly the electricity from the previous interval came from (and, using forecasting, where the electricity currently used is produced). Using a mobile or network connected device or a screen on the energy control system, consumers can see trends and compile statistics.

Adaptive behaviour

Grid operators may influence the market using fluctuating criteria to optimize power flow within their grids. Consumers may combine economic thresholds with their original goals or act preemptively in support or refusal of specific means of electricity generation (e.g., abstain from energy consumption at times when green RTGO would be available but the amount is small next to nuclear production).

Categorizing and labeling

Trusted third parties can offer controlling and labeling for electricity suppliers, making it easier for consumers to make their choices and for suppliers to advertise the properties of their technologies.

Tractability of primary energies through energy storage

RTGOs offer the distinctive advantage that energy that is temporarily stored can maintain its providence, subtracting only the proportional loss due to storage efficiency. For example, if at time t_0 , a battery charges with 1266.372 Wh. For that amount it purchases RTGO. Over a time Δt , it stores the energy, losing 165.782 Wh. At time $t_1 = t_0 + \Delta t$, the battery discharges the remaining energy back into the grid, producing an RTGO over 1100.590 Wh (the difference between charge and loss) for another consumer. The RTGO contains the providence information for the electric energy production credit to the original RTGO purchase and for the storage.

Due to coupling of the RTGO with the physical delivery of the electricity and due to the fact that “location information” can be embedded in the RTGO, there is a possibility to make more cost representative and transparent electricity supply. Some examples:

- In case a supplier imports electricity from neighbouring countries, the system of RTGO makes it possible to obtain a real time operative state which can identify such importation.

- An end user can choose to consume less electricity at moments in time that the supplier cannot deliver real time renewable electricity

5 The system of RTGO can be used to certify the real time operative state including the origin of stored electricity in batteries, pumped hydro or any other storage technology. While charging, the RTGO can be stored together with the electricity and used again when discharging.

10 Energy efficiency and demand side flexibility in the end have the same goal: reducing CO₂ emissions. Nevertheless, energy efficiency programs and charters are not compatible with demand side flexibility. Many industrial processes are fine-tuned in order to operate at the lowest energy consumption possible. By activating flexibility, the industrial process might be pushed out of its “sweet spot” resulting in a higher energy consumption per produced unit. If this activation results in a higher capability of the grid to absorb renewable energy and curtailment can be avoided, however, there is a clear benefit for the system while the customer is punished from an energy-efficiency point of view. For that reason, there is a need for a new definition of “energy-efficiency” and it makes sense that it should be related to the ability to absorb renewable energy. Especially, when electricity is bought from the grid it is impossible to relate extra consumption with the extra consumption of renewable energy. This becomes possible by means of RTGO. New definitions of energy-efficiency can be developed which are not only based on the amount of electricity which has been used but which takes the source of energy into account as well.

For domestic Energy Applications:

- 25
- Smart electricity meters can be updated with the capacity to receive, store, aggregate, RTGO (and parts of RTGO) for ease of inspection and (automated) validation and trading.

For domestic and industrial energy applications:

30 Devices and products that are ready to integrate RTGO and react on near-real-time, including:

- Battery Management Systems extended with RTGO-based control
- EV chargers with integrated RTGO functionality
- Energy market clearing algorithms that take RTGOs into account

- Battery Management Systems enhanced with integrated RTGO-based control functionality.
 - Thermostatic control units with integrated RTGO functionality
 - Forecasters for (local) green energy production, RTGO demand and pricing.
- 5 Energy Traders using Energy Markets can trade energy separately or in combination with RTGO. Which of these options is best will depend on the circumstances and the type and volatility of the market.
- Novel market clearing algorithms will be designed that integrate supply and demand of RTGO.
- 10 • Market forecasters will be adapted to integrate RTGO demand and pricing.

Applications for Energy suppliers, Aggregators and BPR:

New types of contracts can be designed that take advantage of the power of RTGO:

- Suppliers and Aggregators can create new types of contracts with “real time guarantees”. While a 100% real-time guarantee may be difficult today, contracts can
- 15 stipulate that a certain minimum percentage of real time renewable energy should be delivered. As explained above, the percentage of real time renewable energy is an indicator of the actual effort of the supplier to provide renewable energy to its consumers.

Sectors in which the technology can be valorized

- 20 The whole electricity sector, including:
- Energy Suppliers
 - Grid operators
 - Aggregators
 - The Energy storage technology sector
- 25 • Producers of grid assets

In accordance with another embodiment of the present invention software may be implemented as a computer program product which has been compiled for a processing engine to carry out any of the methods of the present invention or is compiled to execute in

30 an interpretative virtual machine such as the JavaTM Virtual Machine. A device such as a controller 46, 47, 48, 49 may comprise logic encoded in media for performing any step of the steps of the methods according to embodiments of the present invention. Logic may comprise software encoded in a disk or other computer-readable medium and/or

instructions encoded in an application specific integrated circuit (ASIC), field programmable gate array (FPGA), or other processor or hardware. A device will also include a CPU and/a GPU and memory, the CPU and/or GPU having a processing engine able to execute software of the present invention.

5

The computer program product may be stored on a non-transitory signal storage medium such as an optical disk (CD-ROM or DVD-ROM), a digital magnetic tape, a magnetic disk, a solid state memory such as a USB flash memory, a ROM, etc.

- 10 The software can be embodied in a computer program product adapted to carry out the following functions when the software is loaded onto the respective device or devices and executed on one or more processing engines such as microprocessors, ASICs, FPGAs etc.:

15 computer based method for determining the operative state of an electricity supply or distribution network or system in which first energy deriving from renewable energy sources is introduced into the electricity supply or distribution network or system and consumed together with second energy produced by other sources, so as to be distributed therewith to predetermined consumer points in the electricity supply distribution network or system,

20

associating the first energy to a guarantee of origin, whose economic value is proportioned to the first energy production over a limited time,

wherein the amount of energy defined in a guarantee of origin is the amount generated in the limited time being a time period between five minutes and one hour, and the guarantee
25 of origin disclosing a topological or topographical location at which the first energy was generated or the location within the electricity supply or distribution network or system where the first energy was injected into the electricity supply or distribution network or system, all of the guarantees of origin together defining and representing an operative state of the electricity supply or distribution network or system.

30

The software can be embodied in a computer program product adapted to carry out the following functions when the software is loaded onto the respective device or devices and executed on one or more processing engines such as microprocessors, ASICs, FPGAs etc.:

managing computer connections over one or more communication networks, collecting electrical energy credits represented by the guarantees of origin, assigning credits on the basis of purchase orders received from one or more consumers of the first energy,

- 5 calculating in a consumer point a total energy consumption in a plant served thereby, storing a number of credits and deducting from the number of credits a quantity of credits on the basis of corresponding first energy consumption by the plant.

- 10 The software can be embodied in a computer program product adapted to carry out the following functions when the software is loaded onto the respective device or devices and executed on one or more processing engines such as microprocessors, ASICs, FPGAs etc.:

- storing first energy in one or more electricity storage devices and feeding the stored first
15 energy to the electricity supply or distribution network or system with an associated guarantee of origin,

converting first energy to gas and associating a guarantee of origin with the gas.

- 20 The software can be embodied in a computer program product adapted to carry out the following functions when the software is loaded onto the respective device or devices and executed on one or more processing engines such as microprocessors, ASICs, FPGAs etc.:

- measuring electrical energy generated at a consumer point and to issue a guarantee of
25 origin,

generating guarantees of origin for energy production by CHP, gas or oil fired power stations, nuclear power stations, hydroelectric power stations or similar.

- 30 The software can be embodied in a computer program product adapted to carry out the following functions when the software is loaded onto the respective device or devices and executed on one or more processing engines such as microprocessors, ASICs, FPGAs etc.:

Recording a guarantee of origin of an energy quantity in a distributed ledger,

recording any of ownership and energy source/type in a distributed ledger.

5 The software can be embodied in a computer program product adapted to carry out the following functions when the software is loaded onto the respective device or devices and executed on one or more processing engines such as microprocessors, ASICs, FPGAs etc.:

performing one remedial action based on the operative state,

10 wherein the operative state includes guarantees of origin generated with respect to first energy being generated at a topological or topographical location or a location within the electricity supply or distribution network or system on one side of a congestion,

15 carrying out the remedial action by limiting electricity supply or distribution to electrical energy which has a guarantee of origin that reduces the congestion,

reducing countertrading or redispatching,

20 the remedial action is tracking volatility of renewable energy sources using the guarantees of origin,

the remedial action is delaying Grid Fortification.

25 The software mentioned above can be stored on a non-transitory signal storage medium, such as an optical disk (CD-ROM or DVD-ROM); a magnetic tape, a magnetic disk, a ROM, or a solid state memory such as a USB flash memory or similar.

30 While the invention has been described hereinabove with reference to a number of embodiments, this is done to illustrate and not to limit the invention, the scope of which is determined by the accompanying claims. The skilled person will appreciate that features disclosed herein in connection with individual embodiments may be combined with features from other embodiments to obtain the same technical effects and advantages, without departing from the scope of the invention.

Claims

1. A system for generating electrical energy certificates, herein called Real-Time Guarantees of Origin, RTGOs, to certify aspects of electrical energy generated at a given power generation facility or group of facilities (42, 43, 44), the system comprising:
- 5 determining means (9, 46, 47, 48, 49), provided for determining amounts of electrical energy generated at said facility or group per time interval and fed into an electrical power grid (41) per time interval;
- RTGO issuing means (11, 17, 46, 47, 48, 49) in communication with said
- 10 determining means, provided for issuing RTGOs which each comprise:
- the amount of electrical energy that was generated at said facility or group and fed into the grid in the respective time interval,
 - energy type information identifying one or more types of the generated electrical energy,
 - 15 - validity information identifying the time interval in which the generated electrical energy was fed into the grid, the time interval being between 5 minutes and one hour,
 - location information identifying a location of said facility or group.
- 20 2. The system according to claim 1, wherein the determining means (9, 46, 47, 48, 49) comprises, or is communicatively connected to, at least one measuring and recording device (9), or includes a power or energy sensor.
3. The system according to claim 2, wherein the at least one measuring and recording
- 25 device (9) comprises at least one smart meter (11).
4. The system according to any one of the preceding claims, wherein the RTGO issuing means is a component of a smart meter (11) or is formed by a computer (17) which is communicatively connected to a smart meter (11).
- 30 5. The system according to any one of the preceding claims, wherein the issued RTGOs are certificates in electronic form and wherein the system is provided for communicating the RTGOs over one or more communication networks.

6. The system according to any one of the preceding claims, wherein each of the issued RTGOs has a unique identifier.

7. A computer based system for determining the operative state of an electricity supply or distribution network in which first energy deriving from renewable energy sources is introduced into the electricity supply or distribution network and consumed together with second energy produced by other sources, so as to be distributed therewith to predetermined consumer points in the electricity supply or distribution network,

wherein the computer based system comprises a plurality of RTGO generation systems according to any one of the preceding claims, and

wherein each of said plurality of RTGO generation systems is associated with a renewable power generation facility or group of facilities, such that the RTGOs issued by the RTGO generation systems together define and represent an operative state of the electricity supply or distribution network.

8. The computer based system according to claim 7, further comprising one or more computing systems provided for ensuring that each RTGO, or fraction thereof, can be matched with consumption only once and only with synchronous consumption.

9. The computer based system according to claim 7 or 8, further comprising means for generation of guarantees of origin for energy production by combined heat and power, CHP, gas or oil fired power stations, nuclear power stations, hydroelectric power stations, a global warming reducing electricity source or similar.

10. The computer based system according to any of claims 7-9, wherein the RTGOs and/or other guarantees of origin are recorded in a distributed ledger.

11. The computer based system according to any of claims 7-10, wherein the system is adapted to perform a remedial action based on the operative state.

12. The computer based system according to claim 11, wherein the operative state includes RTGOs with respect to the first energy being generated at a topological or topographical location or a location within the electricity supply or distribution network on one side of a congestion.

13. The computer based system according to claim 11 or 12, wherein the system carries out the remedial action by limiting electricity supply or distribution to electrical energy which has a guarantee of origin that reduces the congestion.

5 14. The computer based system according to any of claims 11-13, wherein the remedial action is tracking volatility of renewable energy sources using the guarantees of origin, or wherein the remedial action is delaying Grid Fortification.

10 15. A computer based method for generating electrical energy certificates, herein called Real-Time Guarantees of Origin, RTGOs, to certify aspects of electrical energy generated at a given power generation facility or group of facilities (42, 43, 44), the method comprising:

15 determining, by means of determining means (9, 46, 47, 48, 49), amounts of electrical energy generated at said facility or group per time interval and fed into an electrical power grid (41) per time interval;

issuing RTGOs, by means of RTGO issuing means (11, 17, 46, 47, 48, 49) in communication with said determining means, wherein each RTGO comprises:

- the amount of electrical energy that was generated at said facility or group and fed into the grid in the respective time interval,
- 20 - energy type information identifying one or more types of the generated electrical energy,
- validity information identifying the time interval in which the generated electrical energy was fed into the grid, the time interval being between 5 minutes and one hour,
- 25 - location information identifying a location of said facility or group.

16. The computer based method according to claim 15, wherein the determining means (9, 46, 47, 48, 49) comprises, or is communicatively connected to, at least one measuring and recording device (9), or includes a power or energy sensor.

30

17. The computer based method according to claim 15, wherein the at least one measuring and recording device (9) comprises at least one smart meter (11).

18. The computer based method according to any one of claims 15-17, wherein the RTGO issuing means is a component of a smart meter (11) or is formed by a computer (17) which is communicatively connected to a smart meter (11).

5 19. The computer based method according to any one of claims 15-18, wherein the issued RTGOs are certificates in electronic form and wherein the RTGOs are communicated over one or more communication networks.

10 20. The computer based method according to any one of claims 15-19, wherein each of the issued RTGOs has a unique identifier.

21. A computer based method for determining the operative state of an electricity supply or distribution network in which first energy deriving from renewable energy sources is introduced into the electricity supply or distribution network and consumed
15 together with second energy produced by other sources, so as to be distributed therewith to predetermined consumer points in the electricity supply or distribution network,

 wherein a plurality of RTGO generation systems are provided, configured for generating RTGOs according to the method of any one of claims 15-20, and

 wherein each of said plurality of RTGO generation systems is associated with a
20 renewable power generation facility or group of facilities, such that the RTGOs issued by the RTGO generation systems together define and represent an operative state of the electricity supply or distribution network.

22. The computer based method according to claim 21, wherein one or more computing
25 systems ensure that each RTGO, or fraction thereof, can be matched with consumption only once and only with synchronous consumption.

23. The computer based method according to claim 21 or 22, wherein further guarantees of origin are generated for energy production by combined heat and power, CHP, gas or oil
30 fired power stations, nuclear power stations, hydroelectric power stations, a global warming reducing electricity source or similar.

24. The computer based method according to any of claims 21-23, wherein the RTGOs and/or other guarantees of origin are recorded in a distributed ledger.

25. The computer based method according to any of claims 21-24, wherein a system performs a remedial action based on the operative state.

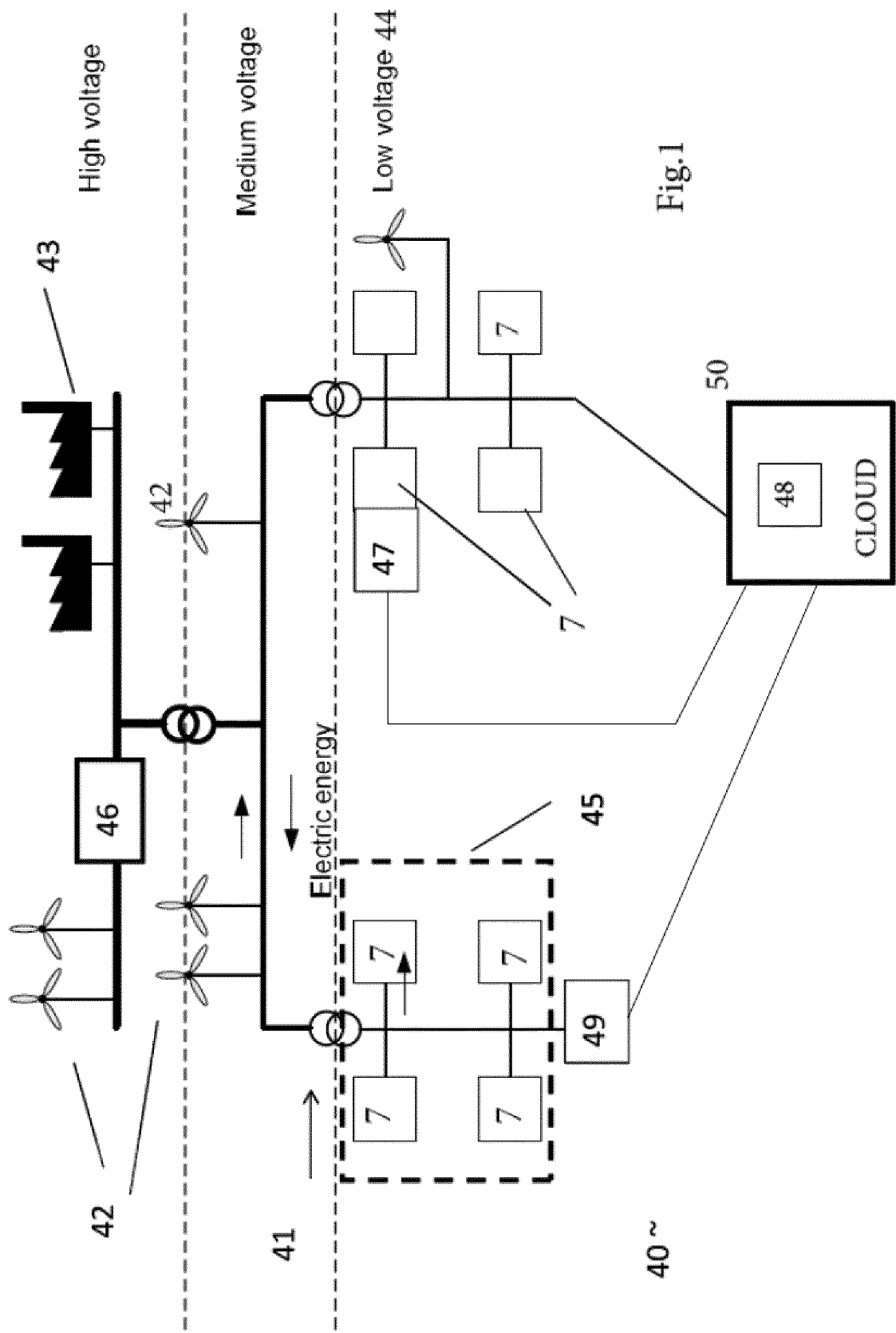
26. The computer based method according to claim 25, wherein the operative state
5 includes RTGOs with respect to the first energy being generated at a topological or topographical location or a location within the electricity supply or distribution network on one side of a congestion.

27. The computer based method according to claim 25 or 26, wherein the system carries
10 out the remedial action by limiting electricity supply or distribution to electrical energy which has a guarantee of origin that reduces the congestion.

28. The computer based method according to any of claims 25-27, wherein the remedial
15 action is tracking volatility of renewable energy sources using the guarantees of origin, or wherein the remedial action is delaying Grid Fortification.

29. A computer program product which, when executed on a processing engine, performs the method of any of the claims 15-28.

20 30. A non-transitory signal storage medium storing the computer program product of claim 29.



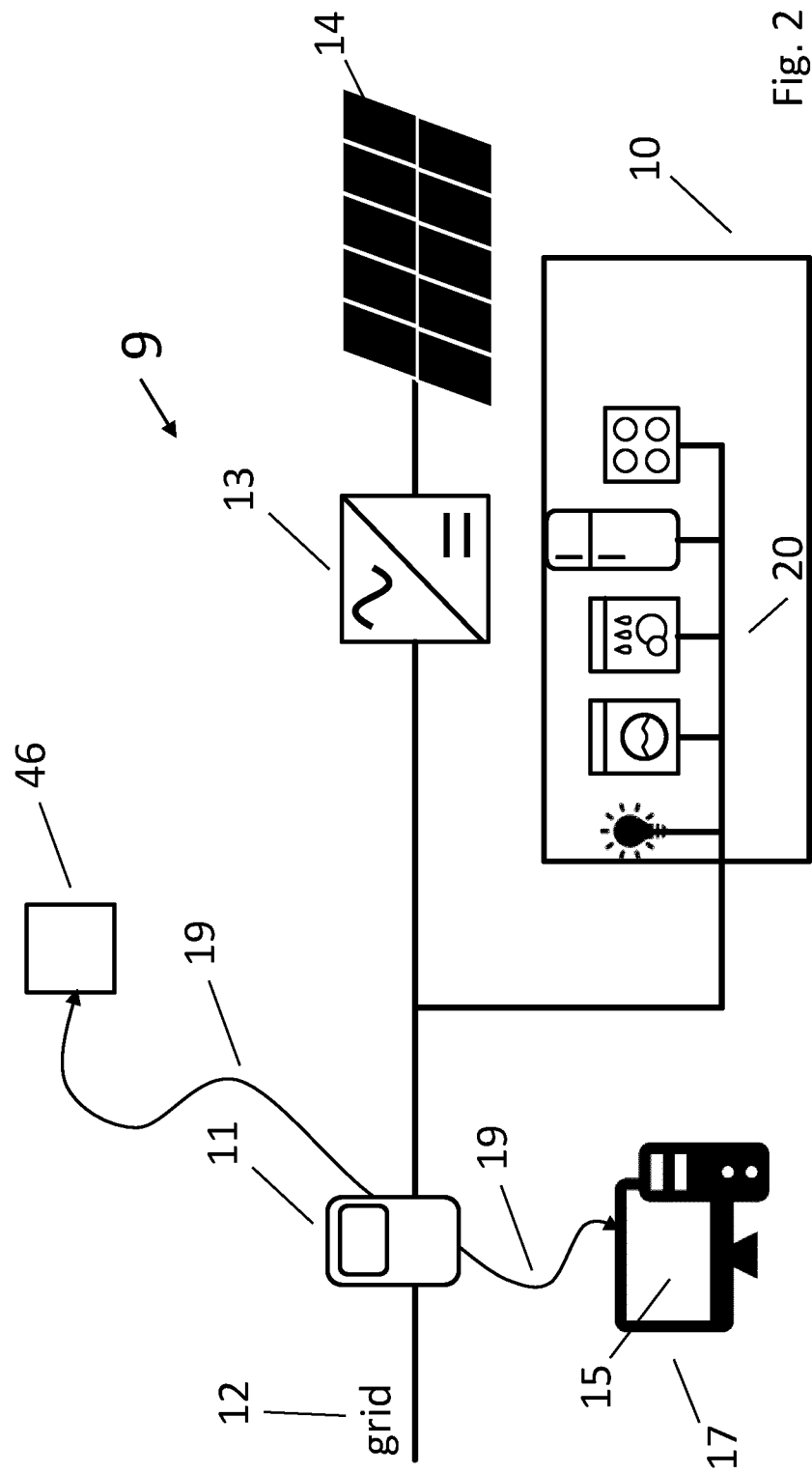


Fig. 2

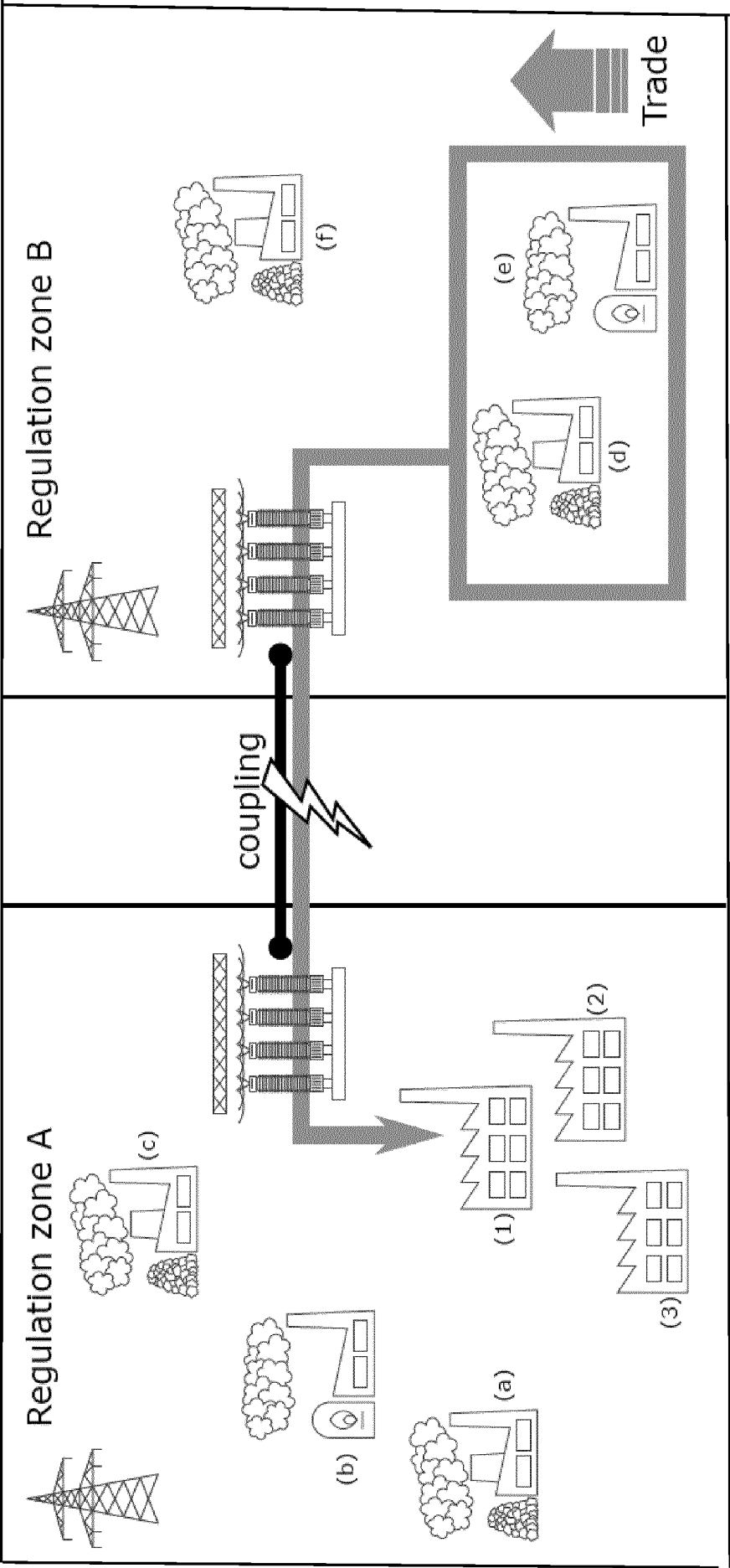


Fig.3

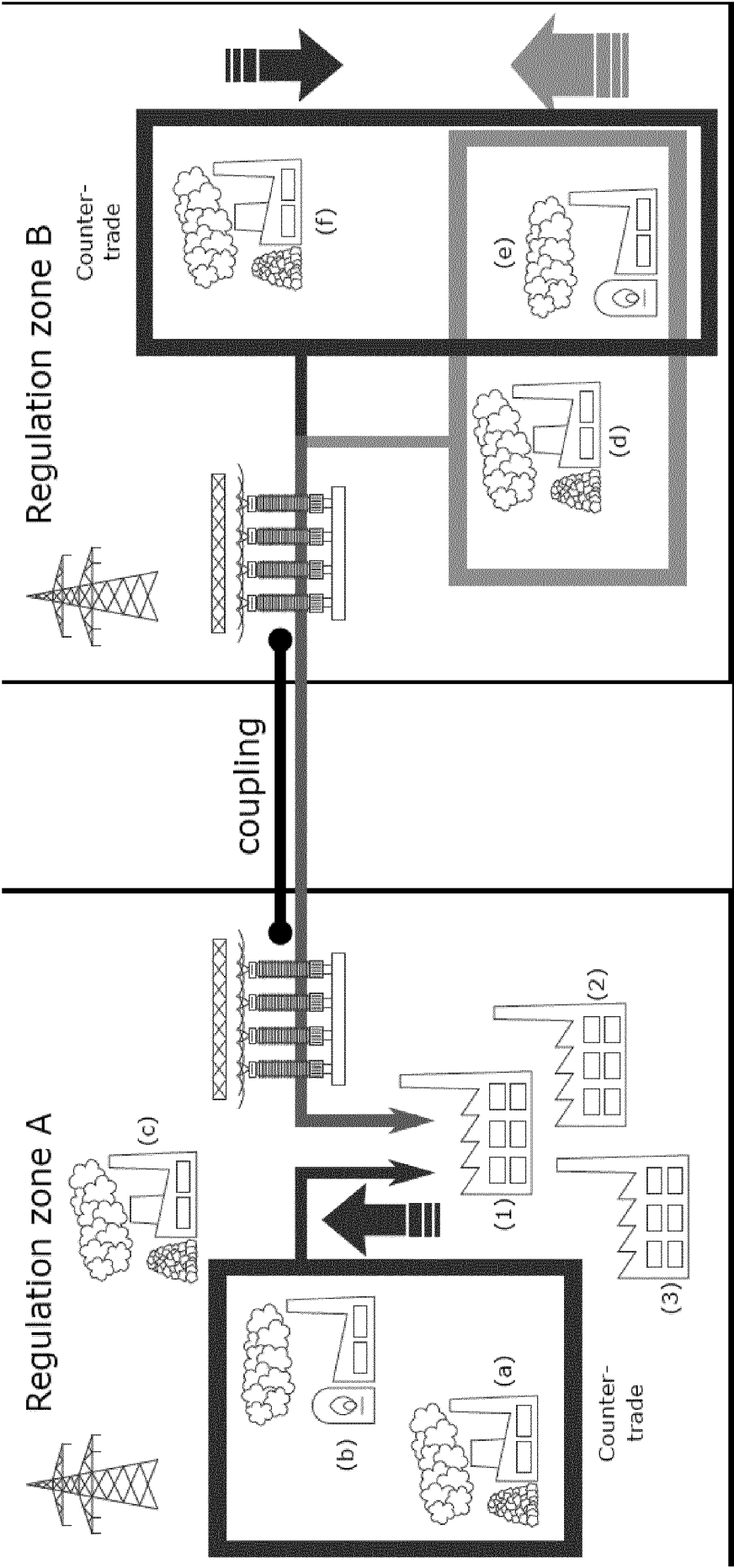


Fig.4

5/5

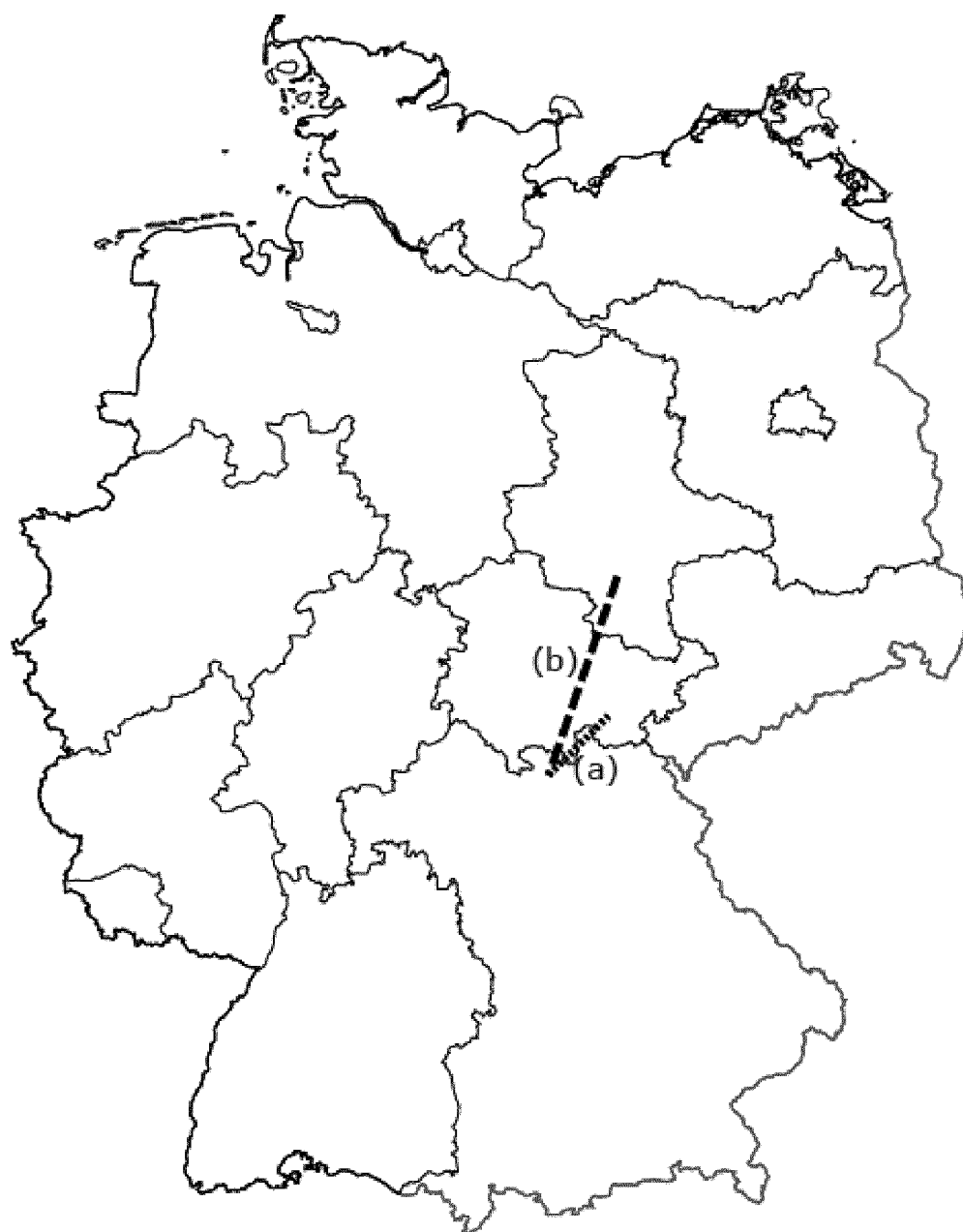


Fig.5